IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of: **STEVEN HILL**	)	Atty Docket No.: **78811 (135-2(1) US)**
Serial No. **10/761,338**	)	Art Unit: **2883**
Filing Date: **JANUARY 22, 2004**	)	Examiner: **DEREK DUPUIS**
Confirmation No. **2678**	)	
For: **BROADBAND OPTICAL PUMP SOURCE FOR PLANAR OPTICAL AMPLIFIERS, PLANAR OPTICAL CIRCUITS AND PLANAR OPTICAL LASERS FABRICATED USING GROUP IV SEMICONDUCTOR NANOCRYSTALS**	)	

DECLARATION UNDER 37 CFR 1.131

Mail Stop Amendment
Commissioner For Patents
PO Box 1450
Alexandria, VA 22313-1450

Sir:

City of Ottawa
Province of Ontario, Canada

I, E. Steven Hill, declare that all statements made of my own knowledge are true, and that all statements made on information and belief are believed to be true:

1. I am an applicant of the above-identified patent application and an inventor of the subject matter described and claimed therein.

2. Prior to January 10, 2003, I conceived the idea in Canada and/or the United States of a photonic device

comprising at least one integral waveguide formed from a rare earth doped group IV semiconductor nanocrystal material as described and claimed in the above-identified application.

3. I founded QC Photonics Inc., a predecessor of Group IV Semiconductor Inc, in February 2002 to develop photonic nanotechnology.

4. On December 16, 2002 a corporate overview was prepared detailing photonic devices; such as pump amplifiers, comprising at least one integral waveguide formed from a rare earth doped group IV semiconductor nanocrystal material, which were being developed at QC Photonics Inc, a copy of which is enclosed as Exhibit A.

5. On January 22, 2003, provisional United States Provisional Patent Applications Nos. 60/441,413 and 60/441,413 were filed relating to the present invention.

6. I acknowledge that willful false statements and the like are punishable by fine and/or imprisonment, and may jeopardize the validity of the application or any patent issuing therefrom.

Sworn at the city of Ottawa in the
Province of Ontario, Canada,
this twenty-first day of April, 2006

E Steven Hill

E. Steven Hill

Exhibit A

10/761338

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QCPhotonics

Corporate Overview

December 16, 2002

Corporate Overview

QCPHOTONICS

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- Incorporated in February 2002
- Early stage company, developing photonic nanotechnology with applications in the areas of lighting and telecommunications
- Basic technology concepts have been validated
- Starting the process of filing initial patents
- Close to finalizing $300K research grant from Photonics Research Ontario (PRO) and Materials & Manufacturing Ontario (MMO), government funded technology centers of excellence
- Small focused team with significant photonics, telecom and start-up experience, validating the technology concepts and building the market plan
  - *Steven Hill* - Lead researcher
  - *Peter Mascher* - Professor, Dept. Engineering Physics and William Sinclair Chair in Optoelectronics, McMaster University
  - *Stephen Naor* - Former COO, Digital Fairway Corporation

Core Inventions

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QC Photonics has developed:

1. A rare-earth doped semiconductor nanocrystal material with two critical properties:
   - very large amplification (on order of 2 orders of magnitude greater than is available in optical amplifiers today) due to efficient coupling of input energy to the rare-earth dopant
   - the material exhibits only an insignificant amount of problematic effects that other attempts to develop this material have discovered, in particular the quenching of the florescence (with resultant massive loss of efficiency)

2. Modifications to 3 standard material manufacturing processes used to create and dope the material. These processes:
   - allow the creation of a high concentration of dopant in the material
   - are easily adapted into standard process lines

Technology Breakthrough

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Core inventions are based on:

1. An ability to achieve an increase in the erbium emission cross-section of 2 orders of magnitude greater than current view of what is possible

2. An ability to excite 40 to 50 erbium ions per nanocrystal (compared to current theories that state that only 1 or 2 erbium ions per nanocrystal can be excited)

3. Modifications to standard PECVD and Gas Pryolysis methods that form doped nanocrystals through use of a precursor, without the usual formation of unwanted Silicon Carbide and other contaminants

4. Demonstrated that a broadband pump source can sufficiently excite the nanocrystal material

Overview of the Processes

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- Semiconductor nanocrystal materials (silicon, germanium, lead and tin) are doped with rare earth metals (Erbium, Neodymium, Praseodymium, Thulium)

- Doping is done at very high concentrations (5 to 35 at%) of erbium as compared to common concentrations of 0.03 at% (1/300 of 1 percent) to 0.5 at% (1/2 of 1 percent)

- Doping is achieved through either of three standard processes, common and understood in the industry:
  - Plasma Enhanced Chemical Vapor Deposition (PECVD) - used to create thin films to be deposited onto planar substrates such as silicon, silica, etc.
  - Gas Pryolysis - used to create a spin-on material
  - Solution Growth Process – used to create a spin-on material; least expensive way to produce large quantities of material

Achievements to Date

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Proof of Concept

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- Demonstrated the PECVD process – have produced doped thick film nanocrystal material on 2 substrates (silica, silicon wafers). Resultant material is uniform and doped in high concentration throughout. Rib waveguides have been etched into the materials.
- Demonstrated the Gas Pryolysis process - manufactured doped thick film nanocrystal material and incorporated the material as a glass film applied to silica, silicon and polymer substrates. Resultant material is uniform and doped in high concentration throughout.
- Measured the photoluminescence of the film (laser and LED as pump input). Found that photoluminescence is 2 orders of magnitude higher than standard laser glass (Kiger MM2 Er doped phosphate glass).
- Etched a waveguide into the material and side pumped it with an LED source. Injected a signal laser and measured the optical gain of the system. Found that the usable gain is 2 orders of magnitude higher than standard laser glass.
- Measured the fluorescent lifetime of the film (laser and LED as pump input). Found that there is insignificant concentration quenching.

Initial conclusions - the material is of very high performance in terms of gain, pump power, ease of manufacturability

Benefits of the Technology

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Applied to Pump Amplifiers

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- Low optical power sources can pump the material to the same amplification level as pump lasers generally do today due to the material being efficiently excited:
  - Lower optical power density requirements - 1W to 5W per cm^2 as compared to 1KW to 2KW per cm^2)
  - Correspondingly lower thermal & electrical requirements (5W to 25W as compared to 25W to 50W from elimination of pump laser and thermoelectric cooler.
  - No need for the cost of thermoelectric cooling of the laser pump source (saves 1/2 the cost of the laser power supply)

- Efficient coupling of the input energy to the dopant:
  - Significantly lower integration cost of the material with the pump source
  - Transverse pumping now possible because of lower optical power density, compared to EDFA (Erbium Doped Fiber Amplifier) and EDWGA (Erbium Doped Waveguide Amplifier).

- Process improvements:
  - Several process steps eliminated - compared to Ion Implantation, generally used in fabricating standard low concentration doped materials.

Transverse Pump Amplifier

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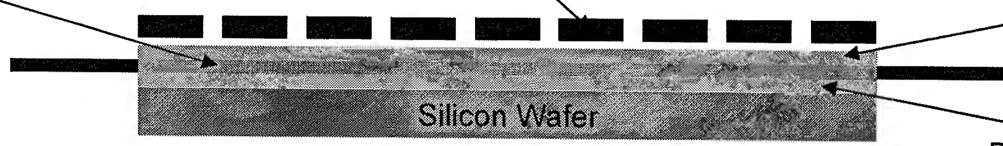
Optical or Electrical Pump Source



- Order of magnitude reduction in <u>manufactured</u> cost of optical amplifiers due to the elimination of pump laser, thermoelectric cooler, power supply for both units and wavelength combiner
- Order of magnitude reduction in <u>power budgets</u> of optical amplifiers due to the substantially reduced power requirements (no pump laser, no cooler to use power)
- Gain is at least an order of magnitude greater in dB/cm than current optical fiber and waveguide amplifiers
- Simplified and lower cost construction of fiber and waveguide amplifiers through use of side pumping and using broadband pump source (LEDs or electrical pumping)
- Amplifier exhibits similar gain to Optical Semiconductor Amplifiers (OSA) but with lower noise figure (comparable to an Erbium amplifier) and more optical channels (hundreds instead of 1 or 2 per device)
- Easy to build devices that cover multiple telecom optical bands (1μm, 1.3μm, 1.5μm, 1.6μm) in 1 device by simply varying the doping. This is difficult to achieve with other technologies.

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Benefits of the Technology

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Applied to Lighting

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- 2 orders of magnitude lower manufacturing cost of any color LED as compared to more conventional color LED due to the use of lower-cost process technologies for Silicon relative to conventional LED materials.
- A single process can make any color LED:
  - Multi-color LEDs easily manufactured on one substrate - Blue, green, red (and of course white) light output
  - Precise color of the output light easily and inexpensively tailored through either controlled doping or electrical tuning
- LEDs can be manufactured onto silicon wafers directly, decreasing costs and increasing reliability through reduced use of discrete components at the board level
- Replaces toxic MOCVD process used in standard LED production with a much less toxic PECVD process, eliminating much of the environmental disposal costs
- Similar power efficiency to conventional LEDs (10% to 15% as compared to 8% to 22%). This enables the benefits of silicon LEDs reviewed above. All other attempts at building silicon LEDs have produced efficiencies of 1/10,000 of 1% at best.

Low-Cost, Low-Power LEDs

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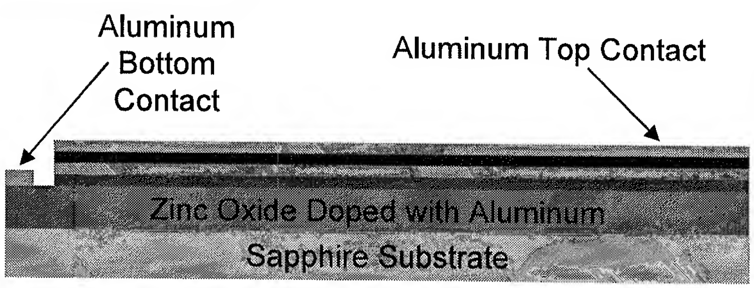
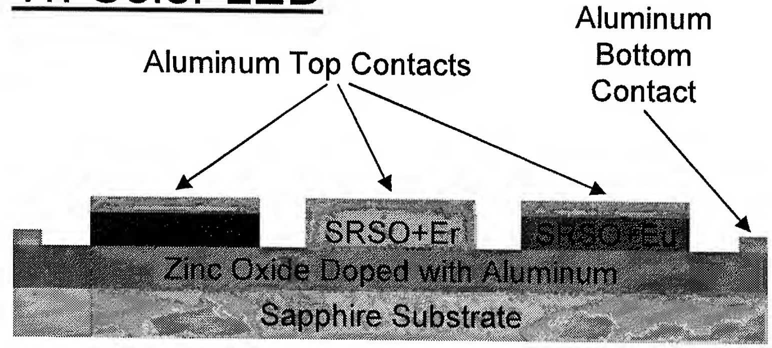
First LED Applications

White LED



Tri Color LED



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- Order of magnitude reductions in power demand and manufacturing cost for flat panel back lighting and visual indications
- White LED has a tunable color of white for precise adjustment
- Color LED can produce any color on 1 substrate
- Color of color LED can be easily changed under logic control
- For overhead area lighting, a 2 mm^2 device will produce the equivalent light to a single 100W incandescent bulb but using only 8W of applied power.
  - Other companies are trying to manufacture LED-based lighting using similar amounts of applied power but due to their reliance on non-silicon technologies, their manufacturing costs and yields are significantly higher and they are having trouble scaling their technologies to sizes required for overhead area lighting.

Lighting Applications

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<u>LED</u>

- Visual indicators on electronic equipment
- Optical sensors for interruption and position indication
- IR communication for remote control of electronic appliances
- Camera auto-focus

<u>Lighting</u>

- Backlighting on electronic equipment
- Area lighting (replacing incandescent lighting)
- Camera flash

<u>Integrated Electronic Circuits</u>

- Optical Interconnection
- Non-evasive blood oxygen and blood-glucose monitoring
- Opto-isolation of power circuits

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Core Technology - Next Steps

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1. Optimize the processes:
   - Vary the concentrations of doping to determine the optimum working range of the dopant
   - Verify long term stability of the film
   - Investigate any volume manufacturing-related issues
2. Optimize the LED pump light coupling to the film
3. Validate the lifecycle of the material
4. Manufacturability – output signal coupling
5. Explore electrical and simultaneous photo/electrical pumping of the film
6. Explore Hybrid system of two different type IV semiconductor in establishing a new nanomaterial with more linear gain (to avoid gain flattening where there are peaks)

#1 thru 4 will be done under PRO / MMO funding

Competition - 1

Lighting - LEDs

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	Pros	Cons
QC Photonics	- very low manufacturing cost (1/100th cost of STM) - very high circuit integration capability - multi-colored LEDs - high brightness - good quantum efficiency (for now)	- early stage company - product not yet commercially available
STMicroelectronics *3rd largest IC manufacturer* *Prototype stage* *no customers yet*	- medium manufacturing cost - very high circuit integration capability - high brightness - good quantum efficiency	- expensive ion implantation process – adds 2 anneal steps to manufacturing process
Lumileds, Osram **NICHA** (cross licensing)	- commercially available product - high brightness - very good quantum efficiency	- expensive, due to:, - use of III/V material and MOCVD process - low wafer yields from small die size - complex multilayer device - costly <u>sapphire</u> substrate
CREE	- commercially available product - high brightness - very good quantum efficiency	- expensive, due to: - use of III/V material and MOCVD process - low wafer yields from small die size - complex multilayer device - costly <u>silicon carbide</u> substrate

Competition - 2

Optical Amplifiers

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	Pros	Cons
QC Photonics Waveguide amplifier	- very low manufacturing cost - very high circuit integration capability - very small size (2 x 2 x 1/2 cm) - low operating cost (no pump laser, cooling) - very wide gain (3 to 20 dB) - no material limitation on no. of wavelengths - low noise figure - very low polarization dependency loss	- early stage company - product not yet commercially available
JDS, Corning, Fujitsu Semiconductor optical amplifier	- commercially available - good circuit integration capability - very small size (2 x 2 x 1/2 cm) - wide gain (6 to 14 dB)	- very expensive and difficult to manufacture - homogeneous gain per device - limited to <u>1 wavelength</u> per device - higher noise figure than EDFAs
Genoa Semiconductor optical amplifier	- commercially available - good circuit integration capability - very small size (2 x 2 x 1/2 cm) - wide gain (6 to 14 dB)	- very expensive and difficult to manufacture - homogeneous gain per device - limited to approx. <u>16 wavelengths</u> per device - higher noise figure than EDFAs

Competition - 3

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Optical Amplifiers

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	Pros	Cons
Teem Photonics, Corning, CILALAS EDWGA	- commercially available - high reliability - medium operating cost (no cooling) - medium gain (6 to 14 dB) - some multichannel capability (up to 4) - Erbium doped waveguide is a 1st step to PLCs	- high manufacturing cost (due to pump laser) - large size (18 x 5 x 2 cm) - requires high power pump laser because of need to split the pump signal - no independent pump control (shared pump) - low circuit integration capability
NP Photonics EDWGA short fiber, under 1 m	- commercially available - low cost coupling to pump laser - multichannel capability - high reliability - medium gain (12 to 14 dB) - some multichannel capability (up to 4)	- high manufacturing cost (due to pump laser) - large size (18 x 5 x 2 cm) - requires high power pump laser because of need to split the pump signal - no independent pump control (shared pump) - low circuit integration capability

Business and Technology Thrusts

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Key Elements

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- Two lines of business:
  - Lighting - LED based devices
  - Planar Lightwave Circuits (PLCs) – optical amplifiers the initial PLC business

- Fast market traction with lighting products first, optical amplifiers second

- One core research program feeding both market thrusts:
  - early-on research drive will be through university labs (McMaster)
  - initial research goals are a) to refine and validate existing inventions; b) characterize the performance range of the materials and selected typical devices;
  - Secondary goal is to locate other markets (ex. defense, space) – small program

- Products developed within the company:
  - possibly jointly with partners
  - possibly with university assistance
  - products - materials vs. devices to be explored (risk vs. reward tradeoff)

- Some markets will be entered through licensing of IP, but likely this will not include lighting or optical amplifiers

- Initial thinking is to be a fabless semi or to use the fabs of partners

Year 1 Milestones

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Preliminary View

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Q1 - January to March 2003

- File provisional patents ($25K required)
- Complete arrangements for research funding from PRO/MMO ($290K)
- Raise $50K to $75K to fund business planning and corporate activities
- Complete a detailed research / technology refinement plan for Year 1 and high-level plan for Year 2
- Deliver on research milestones for Q1
- Develop initial view of the lighting market, for business planning and industrial partnership explorations
- Initial industry partnership explorations - if possible, close a partnership in the lighting space

Q2 - April to June 2003

- Complete a detailed market and product plan for lighting, including clear business context
- Deliver on research milestones for Q2
- Raise $500K to $2M for business / productization / market planning / corporate activities

Q3 - July to September 2003

- Complete a <u>preliminary</u> market and product plan for optical amplifiers, including clear business context
- Deliver on research milestones for Q3
- Close an industrial partnership in the optical amplifier space

Q4 - October to December 2003

- Enter the market for lighting with available simple prototype products (this may be aggressive)
- Complete a detailed business and strategic plan for the company's overall business
- Raise additional investment as necessary
- Deliver on research milestones for Q4
- Complete a detailed research / technology refinement plan for Year 2

Key Personnel

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Steven Hill

- 20 years of wide ranging photonic, laser, and LED development and modeling experience at Corning and other companies. Founder and chief physicist responsible for new photonic device research at PhotoNami Inc.
- 7 patents pending in the areas of optics, semiconductors, devices and switching

Dr. Peter Mascher

- Professor and William Sinclair Chair in Optoelectronics, Dept. Engineering Physics, McMaster University
- Main focus of research is in the development of improved processes for semiconductor lasers, the fabrication of compact laser / detector systems, plasma deposition, defect structures in semiconductors.

Stephen Naor

- COO of Digital Fairway Corporation, a company delivering telecom productivity software. Mr. Naor was with the company from inception until mid-2002 and built the team that delivered $11M of sales in its 2nd year of operation.
- Broad telecom and IT background as a senior manager and executive at Nortel and Newbridge with 16 years experience in sales, marketing, business/product management, systems engineering and R&D.